Development of a mathematical model for tsetse population dynamic to optimize the control in the Niayes (Senegal)

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Plan

Context

- The Senegalese government aims to control trypanosomosis from the Niayes region by eradicating the tsetse vector, Glossina palpalis gambiensis
- In 2005, the Senegalese government initiated a control campaign called ≪Projet de lutte contre les glossines dans les Niayes≫ with a main objective to eradicate tsetse fly in the Niayes area.

Study area

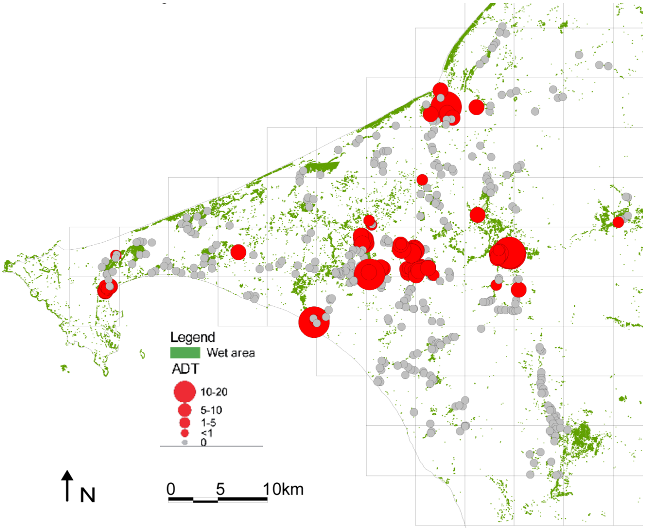


FIGURE: Distribution of tsetse flies in the Niayes area

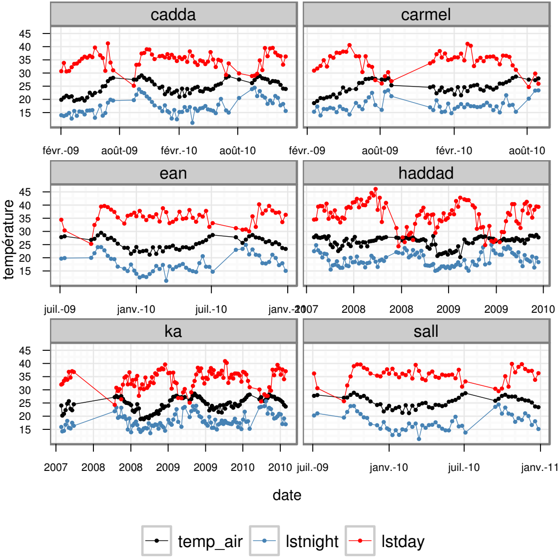
Objectives

- Determination of temperatures "feeled" by tsetse
- Establish a mathematical model to optimize the control measures
- Estimation of the model parameters by fitting the model to field data (densities , age structure)
- Establish the map of distribution
- Establish the metapopulation model using the tsetse map of distribution
- Optimize the control processes measures for tsetse eradication in the Niayes

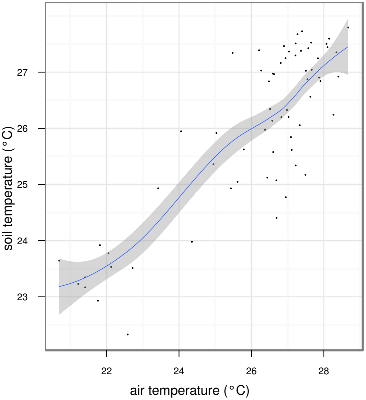
The data

According to the Tsetse biology and ecology, the tsetse life cycle is dependent on the environmental and climatic conditions.
We focused on the influence of average daily temperature (θ_t) on tsetse population dynamics.
Field meteorological data are available in the study area and will be modeled using Modis data.

Temperature / Modis



Temperature soil/air



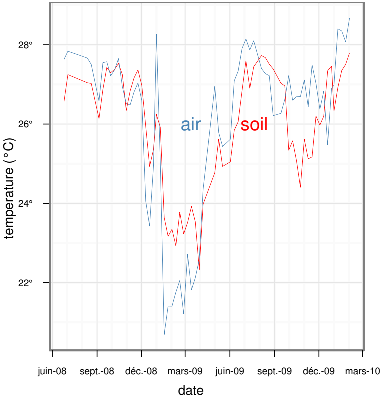
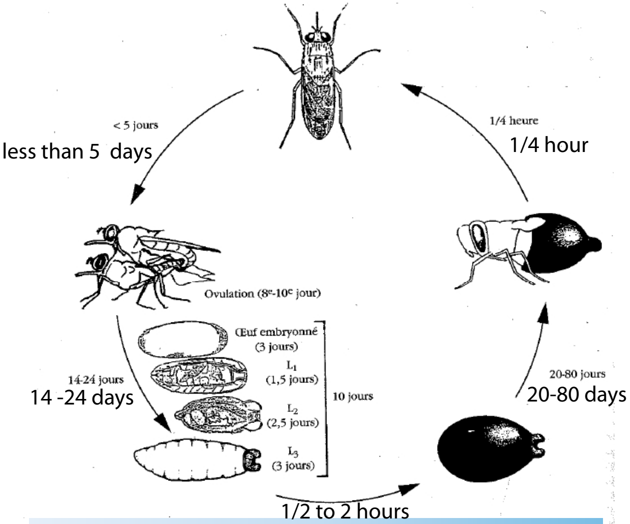


FIGURE: correlation between air temperature and soil temperature (Haddad)

Tsetse Life Cycle



Reproduction cycle of a Tsetse Fly

effect of the temperature on the tsetse development

The daily contribution of the temperature (θ_t) on tsetse population dynamics is obtained by using Hargrove equation :

daily contribution of temperature on the pupal stage

$$pp = (\theta_t - 24) * a_1 + b_1;$$

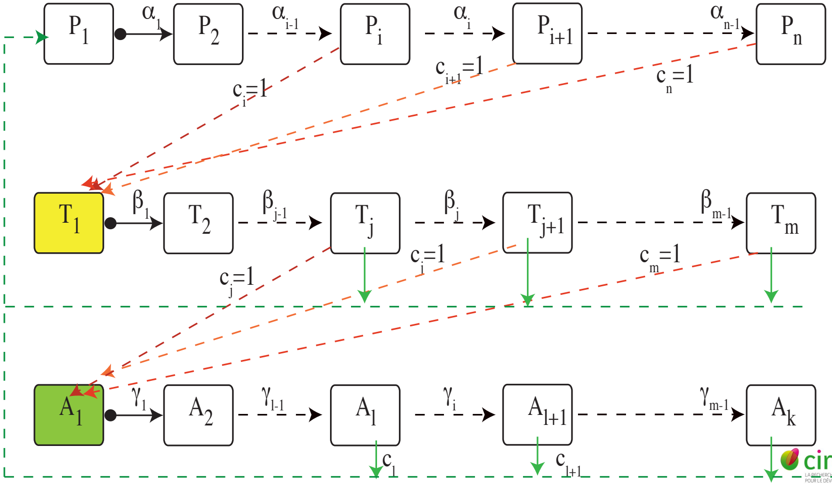
daily contribution of temperature on the teneral stage

$$flp = (\theta_t - 24) * a_2 + b_2;$$

daily contribution of temperature on the adult stage.

$$lp = (\theta_t - 24) * a_3 + b_3;$$

Conceptual Model



Conceptual Model

$$
\left\{
\begin{array}{rl}
P_1 = & \sum c_i(\theta_t) F_i A_i \\
P_2 = & c_2(\theta_t)\alpha_1 P_1 \\
\vdots & \\
P_n = & c_n(\theta_t)\alpha_{n-1} P_{n-1} \\
T_1 = & \sum(1 - c_i(\theta_t))\alpha_i P_i \\
T_2 = & c_2(\theta_t)\beta_{n+1} T_1 \\
\vdots & \\
T_m = & c_m(\theta_t)\beta_{m-1} T_{m-1} \\
A_1 = & \sum(1 - c_i(\theta_t))\beta_i T_i \\
A_2 = & c_2(\theta_t)\gamma_2 A \\
\vdots & \\
A_k = & c_k(\theta_t)\gamma_{k-1} A_{k-1}
\end{array}
\right. \tag{1}
$$

En posant :

$$
X_t = \begin{pmatrix} P_1 \\ P_2 \\ \vdots \\ P_n \\ T_1 \\ T_2 \\ \vdots \\ T_m \\ A_1 \\ A_2 \\ \vdots \\ A_k \end{pmatrix} \tag{2}
$$

Conceptual Model

$$X_{(t+1)} = A_{\theta_t}.X_t \qquad \text{where} \qquad A_{\theta_t} \text{ is equal to}$$

$$\left(\begin{array}{ccccccc}
0 & \dots & 0 & c_j(\theta_t)F_j & 0 & \dots & c_k(\theta_t)F_k \\
c_1(\theta_t)\alpha_1 & 0 & \vdots & 0 & \dots & \dots & 0 \\
0 & c_2(\theta_t)\alpha_2 & 0 & 0 & \dots & \dots & 0 \\
0 & 0 & c_i(\theta_t)\alpha_i & 0 & \dots & \dots & 0 \\
\vdots & \ddots & \vdots & \ddots & \dots & 0 & 0 \\
0 & 0 & \vdots & \vdots & \vdots & \vdots & \vdots \\
(1-c_1(\theta_t))\alpha_1 & \dots & (1-c_i(\theta_t))\alpha_i & 0 & \dots & & 0 \\
0 & 0 & 0 & c_j(\theta_t)\beta_1 & 0 & \dots & 0 \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
0 & 0 & 0 & (1-c_j(\theta_t))\beta_1 \dots & (1-c_{j+1}(\theta_t))\beta_j & 0 \dots & 0 \\
0 & 0 & \dots & 0 & c_{k-1}(\theta_t)\gamma_{k-1} & 0 & 0 \\
0 & 0 & 0 & \dots & 0 & c_k(\theta_t)\gamma_k & 0
\end{array}\right) \quad (3)$$

- A_{θ_t} is temperature dependent.
- as the mortality is temperature-dependent
- the fecundity is temperature-dependent because the time taken to produce larva is function of the temperature .

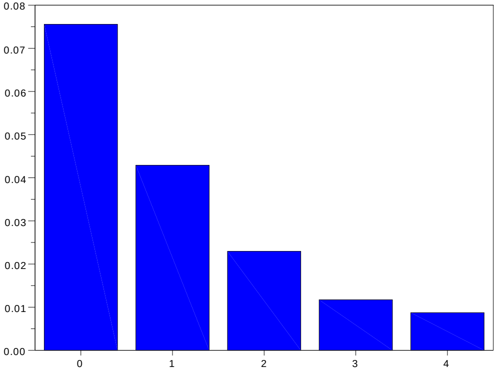


FIGURE: histogram of the frequencies of flies by parity group produce by the model

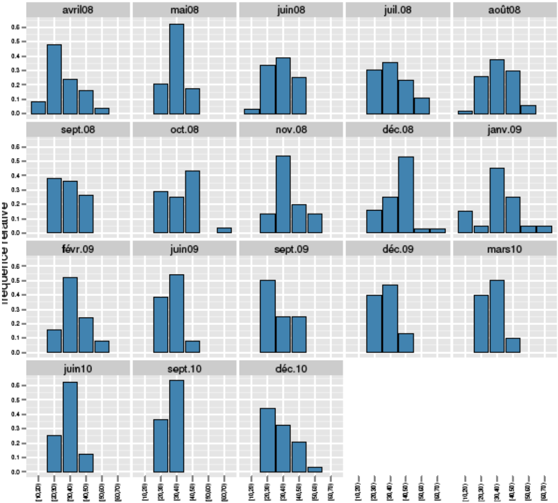


FIGURE: histogram of the frequencies of flies by parity group on the field data

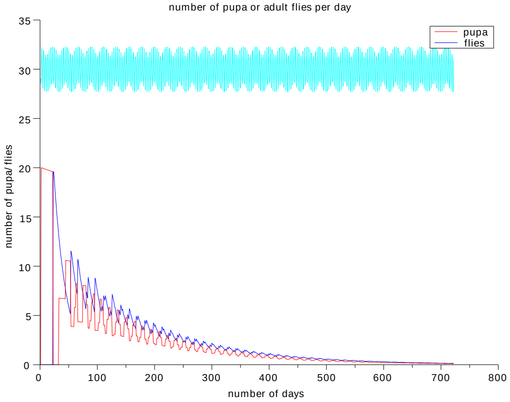


FIGURE: tsetse population dynamic with a temperature around 30° C ($\lambda < 1$)

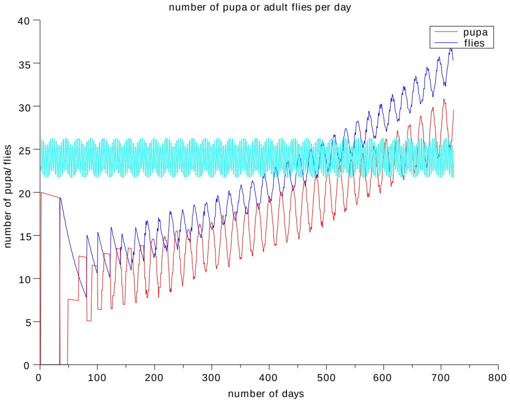


FIGURE: tsetse population dynamic with a temperature around 25° C ($\lambda > 1$)

Perspectives

- parameters estimation (in progress...)
- sensivity analysis and uncertainty analysis
- Tsetse distribution map of suitable habitat

FIN

Thanks for your attention ! ! !...